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Compositional and nutritional studies on two wild edible mushrooms from northwest Spain

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Abstract

The chemical composition and nutritional value of two wild edible mushroom species (*Tricholoma portentosum* and *Tricholoma terreum*) from the northwest of Spain were determined. Content of dietary fibre was high (approx. 45% of dry matter) in both species. Protein content of both species was very similar and close to 16% of dry weight. Essential amino acids accounted for 61.8 and 63.3% of total amino acid contents of *Tricholoma portentosum* and *Tricholoma terreum*, respectively. Leucine, isoleucine and tryptophan were the limiting amino acids in both species. The corrected amino acid scores (PDCAAS) of *Tricholoma portentosum* and *Tricholoma terreum* proteins were low compared with those of casein, egg white and beef but higher than those of many vegetable proteins. Content of fat was low (5.7% for *Tricholoma portentosum* and 6.6% for *Tricholoma terreum*) in both species, with oleic and linoleic acids accounting for more than 75% of total fatty acids. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Fungi-edible; Nutritional values; Amino acids; *Tricholoma portentosum*; *Tricholoma terreum*

1. Introduction

In most countries, there is a well-established consumer acceptance for cultivated mushrooms (*Agaricus bisporus, Pleurotus* spp., *Lentinus edodes, Volvariella volvacea, Auricularia* spp. etc.). However, wild edible mushrooms have been traditionally eaten by specific groups of people (local people, enthusiasts and gourmets) and seasonally. Nevertheless, wild mushrooms are becoming more and more important in our diet for their nutritional (Breene, 1990; Coli, Maurizi, Granetti, & Damiani, 1988; Crisand & Sand, 1978), organoleptic (Maga, 1981) and pharmacological (Bobek, Ginter, Jurocovicova, & Kunia, 1991) characteristics.

Several studies have been carried out on the chemical composition and nutritional quality of different species of this type of fungus (Aletor, 1995; Alofe, Odeyemi, & Oke, 1996; Coli, Maurizi, Granetti, & Damiani, 1988; González, Treviño, & García, 1971; Senatore, Dini, Cerri, & Schettino, 1987; Senatore, Dini, & Marino, 1988; Senatore, 1992; Vetter, 1993). *Tricholoma portentosum* (Fr.: Fr) Quél and *Tricholoma terreum* (Sch.: Fr) Kumm are two of the most abundant wild edible mushrooms in the north of Spain. Both are easy to recognize and they are collected in large quantities in pine woods in autumm. The taste and size of their fruiting bodies and their abundance are important factors when considering these mushrooms as potential important foods, with good prospects for industrial use.

Despite these findings, and the potential economic importance of these mushrooms, little work has been carried out on their chemical composition (Kawai, Sugahara, Matsuzawa, Aoyagi, & Hosogai, 1986, Vetter, 1990). In this investigation we have examined the proximate chemical composition, amino acid and fatty acid profiles of proteins and lipids of these two species in order to assess their nutritive potential. Moreover, we have analysed free-amino acids that might be valuable for chemotaxonomical and cultivation purposes, as Senatore (1992) and Nes and Nes (1980) have indicated for other species.

2. Materials and methods

2.1. Sample preparation

Fruit bodies of *Tricholoma portentosum* and *Tricholoma terreum*, collected in Camposagrado pine wood

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near León (northwest Spain), were washed with distilled water, the pileus was removed and placed on trays, freeze-dried and then milled.

2.2. Chemical composition

Proximate analyses were carried out in triplicate, following the ISO procedures (Presidencia del Gobierno, 1979), crude protein (N×6.25) by macro-Kjeldahl, crude fat by Soxhlet and total ash by incineration at 535±15 °C. Neutral detergent fibre (NDF) was estimated by the method of van Soest (1967). Total sugars were determined by the phenol-sulfuric reaction described by Whistler and Wolfrom (1962). Glycogen was estimated using the quantitative method of Glover, described in the spanish official procedures for meat and meat products (Presidencia del Gobieno, 1982). Non-protein nitrogen (NPN) was determined by the method described by De Ketelaere, Demeyer, Vandekerckhove, and Vervaeke (1974).

2.3. Nutritional analysis

The amino acid composition of proteins of the two mushrooms studied was determined by the Wiedmeier, Porterfield, and Hendrich (1982) method after hydrolysis of freeze-dried samples with 6 N HCl for 24 h at 110 °C. A separate portion of the samples was oxidized with performic acid according to the procedure of Moore (1963) and then hydrolyzing with 6 N HCl in order to obtain reliable cystine and methionine values. For tryptophan analysis, samples were hydrolyzed with 5 N NaOH, according to the Hugli and Moore (1972) method.

Protein digestibility was estimated "in vitro" using a multienzyme system developed by Hsu, Vavak, Satterlee, and Miller (1977).

Each essential amino acid was expressed as a percentage of the corresponding amino acid in the reference protein (FAO/WHO/UNU 1985). In order to determine corrected amino acid scoring, these data were multiplied for digestibility.

Fatty acid methyl esters were analysed by gas chromatography (GC) on a Konik-Cromatix KNK 2000 equipped with a flame ionization detector. A stainless steel column (2 m×1/8 inch) packed with 15% DEGS S/Chromosorb W-AW 80/100 was used for separation.

3. Results and discussion

3.1. Chemical composition

The results of the chemical composition are shown in Table 1. In both samples, the dominant compounds were protein and carbohydrate (including fibre). The protein contents of *Tricholoma portentosum* and *Tricholoma terreum* were very similar in both species and close to 155 g kg^{-1} dry weight. The protein was calculated from protein nitrogen (total minus non-protein nitrogen) × 6.25, because it is known that mushrooms contain a significant amount of non-protein nitrogen, generally in the form of chitin in their cell walls.

Table 1
Chemical composition of mushrooms[a]

Compound	*Tricholoma portentosum*	*Tricholoma terreum*
Crude protein[b]	196	201
Real protein[c]	156	154
Lipids	57.7	66.4
Ash	98.9	121
Soluble sugars	182	54.6
Glycogen	15.6	10.6
Neutral detergent fibre (NDF)	301	301
Non-structural polysaccharides [d]	170	270

[a] Values are expressed as g kg^{-1} of dry matter. Results are the averages of three independent determinations.
[b] N×6.25.
[c] (Total N−NPN) ×6.25.
[d] Determined by difference.

Tricholoma portentosum and *Tricholoma terreum* seem to have a normal protein content compared with other edible mushrooms (Crisan & Sand, 1978; Kreula, Saarivirati, & Karanko, 1976; Leichter & Bandoni, 1980; Turner, Kuhnlein, & Egger, 1987). The results agree with those obtained by measuring total amino acid composition (actual protein) (Danell & Eaker, 1992; Gerrits, 1989).

The distribution of different carbohydrate fractions is similar in both species except for soluble sugars which were clearly higher in *Tricholoma portentosum* (18.2 g kg^{-1}) than in *T. terreum* (5.50 g kg^{-1}). These differences appeared to be related to the contents of soluble non-structural polysaccharides. The aqueous extracts of *Tricholoma terreum* are much more viscous and gelatinous than those of *Tricholoma portentosum* (personal observation). Nevertheless, these values are within the range of those reported by Coli et al. (1988).

The sum of NDF plus soluble non-starch polysacharides could be considered as dietary fibre (DF) and represents around 45–50% of dry matter in both species. These results agree with those reported by Turner et al. (1987) for cottonwood mushroom (*Tricholoma populinum*) and Kurasawa, Sugahara, and Hayashi (1982) and Yoshida and Fujimoto (1994) for other wild mushrooms. The fairly high level of fibre in these mushrooms is a desirable characteristic since fibre plays an important role in human diet.

The fat content ranged from 57.7 g kg^{-1} of dry matter in *Tricholoma portentosum* to 66.4 g kg^{-1} in *Tricholoma terreum* and the ash content varied from 98.8 g kg^{-1} to 121 g kg^{-1}, respectively, between the species. These

Table 2
FFA composition of mushrooms[a]

Amino acid	*Tricholoma portentosum*	% of total FAA	*Tricholoma terreum*	% of total FAA
Ser	0.47	4.7	0.60	6.1
Asp[b]	0.55	5.4	0.65	6.6
Glu[b]	2.37	23.7	2.13	21.7
Gly	0.90	9.0	0.50	5.2
Thr	0.48	4.8	0.46	4.6
Ala	1.79	17.9	1.74	17.7
Arg	0.18	1.7	0.06	0.6
Pro	0.22	2.2	0.17	1.8
Met	0.20	2.0	0.25	2.6
Val	0.29	2.8	0.40	4.0
Phe	0.40	4.0	0.35	3.6
Trp	0.33	3.2	0.26	2.6
Leu/Ileu	0.77	7.7	0.75	7.5
Hys	ND[c]		ND[c]	
Lys	0.40	4.0	0.47	4.7
Cys	0.36	3.6	0.35	3.5
Tyr	0.31	3.1	0.32	3.2
Total	10.0		9.5	

[a] Values are expressed as g kg^{-1} of dry matter.
[b] Values for Asp and Glu include asparagine and glutamine, respectively.
[c] ND, not determined.

results are comparable to those obtained by Turner et al. (1987) in other *Tricholomataceae* and by Leichter and Bandoni (1980) and Miric, Lalic, and Miletic (1985) in several wild edible mushrooms.

Free amino acids and their contents in the fruiting bodies of the two mushroom studied are shown in Table 2. The total free amino acid contents are quite similar in both species and no major differences were observed in the amino acid profiles, except for glycine, whose concentration was twice as high in *Tricholoma portentosum* as in *Tricholoma terreum*. The minor differences between these fungi did not appear to be related to the species but to other factors, such as age, and development and the study of FAA patterns may, in this case, not be of value for taxonomical purposes. Glutamic acid, alanine, leucine + isoleucine and glycine are present in large amounts. These mushrooms are especially rich in glutamic acid (≅22% of total) as occurs in other wild and cultivated fungi (Beuchat, Brenneman, & Dove, 1993; Ogawa, Oka, & Sasaoka, 1987; Sato, Aoyagi, & Sugahara, 1985; Senatore, 1990) including species of the genus *Tricholoma* (Fujita, Komemushi, & Yamagata, 1991; Senatore, Dini, Cerri, & Schetinno, 1987).

It is well known that free amino acids, especially highly basic amino acid and glutamic acid contribute to the flavour properties of the mushrooms (Maga 1981; Sugahara, Arai, Aoyagi, & Kunisaka, 1975) thus the high levels of glutamic acid in *Tricholoma portentosum* and *Tricholoma terreum* probably contribute most to their characteristic flavour.

Another possible precursor flavour compound source would be the presence of unsaturated fatty acids (Maga, 1981). Table 3 shows the results of fatty acid composition of the two species examined. The fatty acid profile of other species of *Tricholoma* (Senatore et al., 1987) is also listed for the purpose of comparison. In both species studied, oleic, linoleic and stearic acid were the main fatty acid constituents, as occurs in many other species (Longvah & Deosthale, 1999; Senatore, 1990). Other fatty acids, for example $C_{12:0}$, $C_{14:0}$, $C_{16:1}$ and $C_{18:0}$, were only found in very small amounts. It is also important to point out that, in contrast to other fungi (Stancher, Procida, & Calabrese, 1992), no other fatty acids with an odd number of carbon atoms have been identified. All species cited in Table 3 are characterized by a high concentration of unsaturated fatty acids, and more than 75% of total fatty acid content. Nevertheless, the oleic acid content in *Tricholoma portentosum* and *Tricholoma terreum* is much higher (58.0 and 56.7%) than in other *Tricholoma* sp. reported, while the percentage of linoleic acid is practically half; consequently the L/O ratio is practically the reverse. Realistically, this fact is not of importance from the nutritional point of view, since the amounts of lipid in the fresh edible portion are quite small. However, the L/O ratio could constitute an important parameter from a chemotaxonomic viewpoint and could be useful for the taxonomical differentiation between species of the same genus.

The high levels of linoleic acid in the species studied are probably, together with other compounds, closely related to their flavour since, as Grosh and Wurzenberger (1984) have pointed out, this FFA is the precursor of 1-octen-3-ol, known as the alcohol of fungi, which is the principal aromatic compound in most fungi (Maga, 1981)

3.2. Protein quality

The amino acid compositions of *Tricholoma portentosum* and *Tricholoma terreum* proteins are shown in Table 4. Sixteen amino acids, including tryptophan, were determined. In general, there appeared to be no significant variation between species in amino acid profiles of the mushroooms studied. Essential amino acids accounted for 61.8 and 63.3% of total amino acid contents of *Tricholoma portentosum* and *Tricholoma terreum,* respectively. Mostly, the essential amino acid were present in fairly high amounts. Some, such as lysine, which is usually limiting in many vegetable foods, and threonine and valine, were present in amounts exceeding the FAO/WHO (1973) reference protein requirements. Only isoleucine, tryptophan and leucine (this latter in *Tricholoma terreum*) were slightly deficient in these mushrooms.

The average level of essential amino acids and the corresponding amino acid scores based on suggested

Table 3
Fatty acid composition of mushrooms[a]

Fatty acids	*Tricholoma portentosum*	*Tricholoma terreum*	*Tricholoma acerbum*[b]	*Tricholoma batschii*[b]	*Tricholoma nudum*[b]	*Tricholoma pardinum*[b]
$C_{12:0}$	0.4	0.2	0.8	T	0.3	0.4
$C_{14:0}$	1.2	0.3	0.5	0.2	0.3	T[c]
$C_{16:0}$	7.6	10.1	16.2	23.0	21.2	18.2
$C_{16:1}$	1.0	0.8	1.1	0.5	1.3	0.7
$C_{18:0}$	3.4	1.8	4.9	5.3	1.9	10.1
$C_{18:1}$	58.0	56.7	5.8	7.1	4.8	4.0
$C_{18:2}$	27.9	29.7	65.6	58.5	63.9	61.4
L/O[d]	0.48	0.52	11.3	8.23	13.3	15.35

[a] Values are expressed as percentage of total fatty acids.
[b] Data reported by Senatore et al. (1987).
[c] T, trace amounts.
[d] L/O, linoleic-oleic acid ratio.

Table 4
Amino acid composition of *Tricholoma portentosum* and *Tricholoma terreum* fruiting body proteins (mg g^{-1} protein)[a]

Amino acid	*Tricholoma portentosum*	*Tricholoma terreum*	Whole hen's egg
Serine/aspartic acid	78.6	85.7	–
Glutamic acid	76.2	75.7	127.4
Glycine	40.6	30.2	33.1
Threonine	94.5	90.7	51.2
Alanine	86.4	84.3	59.2
Arginine	ND[b]	ND[b]	61.0
Proline	38.8	30.9	41.6
Methionine	29.6	34.6	34.6
Valine	77.6	88.7	68.5
Phenylalanine	43.6	66.1	56.3
Tryptophan	9.6	10.6	16.2
Leucine	93.7	81.5	88.2
Isoleucine	37.2	35.8	62.9
Histidine	ND[b]	ND[b]	24.3
Lysine	86.3	76.3	69.8
Cystine	16.2	17.0	24.3
Tyrosine	32.1	30.0	41.6

[a] Average values of three independent determinations.
[b] Not determined.

Table 5
Essential amino acid content and uncorrected and corrected (PDCAAS) amino acid scores of *Tricholoma portentosum* and *Tricholoma terreum* proteins

Essential amino acid	Content (mg g^{-1} protein)		2–5 year old FAO/WHO reference values	Uncorrected amino acid scores[a]		PDCAAS[b]	
	Tricholoma portentosum	*Tricholoma terreum*		*Tricholoma portentosum*	*Tricholoma terreum*	*Tricholoma portentosum*	*Tricholoma terreum*
Histidine	ND[c]	ND	19	ND	ND	ND	ND
Isoleucine	37.2	35.8	28	1.32	1.27	0.96	0.92
Leucine	93.7	81.5	66	1.42	1.23	1.03	0.90
Lysine	86.3	76.3	58	1.49	1.31	1.08	0.95
Methionine + Cystine	45.8	51.6	25	1.83	2.0	1.33	1.46
Phenylalanine + Tyrosine	75.7	96.0	63	1.20	1.52	0.87	1.11
Threonine	94.5	90.7	34	2.70	2.66	1.96	1.94
Tryptophan	9.6	10.6	11	0.87	0.96	0.63	0.70
Valine	77.6	88.7	35	2.21	2.53	1.61	1.85

[a] Uncorrected amino acid scores = Columns I and II/Column III.
[b] PDCAAS = Uncorrected amino acid scores (Columns IV and V) × 72.9% and 73.2% ("in vitro" digestibility of *Tricholoma portentosum* and *Tricholoma terreum* respectively).
[c] Not determined.

patterns for amino acid requirement (Henley & Kuster, 1994) were calculated (Table 5). By using the amino acid scores, we calculated an approximate protein digestibility corrected amino acid score (PDCAAS; Henley & Kuster, 1994), which replaces the previous PER (protein efficiency ratio) for assessing the overall protein quality according to the Nutrition Labeling Regulations of the Food and Drug Administration (FDA, 1993). PDCAAS is the product of the lowest uncorrected amino acid score and the protein digestibility. The protein digestibility should be done as "true digestibility", determined through animal assay. Nevertheless, we calculated PDCAAS of *Tricholoma portentosum* and *Tricholoma terreum* using in vitro multienzyme test results. This multienzyme system did reduce the limitations which were evident for a single enzyme system and gave a better approximation of true digestibility (Hsu et al., 1977). The PDCAAS for *Tricholoma portentosum* and for *Tricholoma terreum* were 0.59 and 0.7, respectively, for tryptophan ($0.87\times72.9/100$ in vitro digestibility and $0.96\times73.2/100$ in vitro digestibility). The results of corrected amino acid score showed that *Tricholoma terreun* had a higher apparent PDCAAS value and therefore had a better nutritional protein quality than the other species studied, which is not strange, since the amino acid content and protein quality in edible fungi widely varies between species and even with the environment where they grow (Wang-Ling, Li-Yuyue, & Yan-Xiaxian, 1990). The protein qualities of these fungi are comparable, above all that of *Tricholoma terreun*, to that of some selected vegetable proteins (FAO/WHO, 1989).

To sum up, the nutritional value of *Tricholoma portentosum* and *Tricholoma terreum* should not be exagerated. However, the protein content and protein quality seem to be high compared with other edible mushrooms (Breene 1990; Danell & Eaker, 1992) and with many vegetables and wild plants (FAO/WHO, 1989).

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